Modelling the future of cereal yields : from technical ineffficiency until price efficiency

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MODELLING THE FUTURE OF CEREAL YIELDS : FROM TECHNICAL INEFFICIENCY UNTIL PRICE EFFICIENCY

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1. INTRODUCTION

The recent compatibility controversy about the CAP reform package and the agricultural Uruguay Round agreement revealed the importance of the cereal productivity evolution. Most certainly, the CAP reform set-aside and other provisions will contribute to keep the cereal EC production below the ceiling which would be imposed by EC-US Blair House agreement. Nevertheless, a few doubts remain, related in particular to the intending grain use in European feed rations and the evolution of cereal yield. On this last issue, the opinions differ notably.

Some say that cereal yields will not continue to increase as a result of genetic improvement at a rate close to the recent historical rate ; in other respects, the farms operating at lower levels of efficiency, have no access to improved husbandry methods ; after all, there will be no incentive to produce beyond the average regional yield. On the other hand, the farmers will be stimulated to increase efficiency by the "shock" of the new lower returns resulting from CAP reform : the cereal price decrease should provide a stimulus to increase the productive efficiency.

Moreover, the future land transactions due to CAP reform, can explicitly entail trades of land from "low ability" to "high ability" farmers which should lead to the extension of improved husbandry methods upon a greater portion of the national acreage ; in other words, the global adjustment of the agricultural economy towards a Pareto optimum requires a technical efficiency level for the global production possibilities set : that leads to the eviction of the lower efficient farmers.

In a general way, the preceding different arguments agree on the fact that the microeconomic efficiency level will probably govern the success of the cereal market price regulation. We adopt this last assumption in this work providing two models, nonparametric and parametric. Different micro efficiency levels are considered since technical inefficiency until the profit maximisation behaviour.

2. TECHNOLOGY ENVELOPMENT

Standard production theory assumes that farmers are profit maximisers (or cost minimisers). This approach specifies a parametric form for the production function. It uses standard statistical techniques to estimate the unknown parameters from the observed data set. this process suffers from the weakness of the maintained hypothesis.

The nonparametric approach to agricultural production relies on less stronger assumptions. It examines the consistency of observed production behaviour with the profit maximisation hypothesis. It's based on the formal economic definition of a production function. A production frontier is determined by using linear programming techniques.

This approach identifies the level of technical efficiency for each observation relative to this frontier. It doesn't provide the path to reach the frontier of production but it only provides a set of points on this frontier that can be achieved.

Consider a production unit j ($j = 1,\dots,J$) transforming a vector of inputs $x_j \in R_+^N$ into an output vector $y_j \in R_+^M$, subject to the technological constraints. We assume that at least one output and one input are positive and that every production unit j used for efficiency comparisons has the same inputs and produces the same outputs, although in varying amounts.

To represent the technology, we use the following observed envelope (or production possibility set) P :

$$P = \{(x,y) / y \geq o \text{ can be produced from } x \geq o\} \quad (1)$$

and we postulate following properties (Banker, Charnes, Cooper, 1984) :

[P1] $(x_j, y_j) \in P$ for all $j = 1,\dots,J$
Each observed input-output vector is contained in the set P

[P2] P is a regular set
P is not empty, P is closed, the null input vector yields zero output and finite inputs can not produce infinite outputs.

[P3] Free (or strong) disposability of inputs and outputs :
If $(x,y) \in P$ and $\bar{x} \geq x$ and $\bar{y} \leq y$ then $(\bar{x},\bar{y}) \in P$ (2)

[P4] Convexity :
If $(x,y) \in P$ and $(\bar{x},\bar{y}) \in P$, if $\alpha \in [0,1]$ then $\alpha(x,y) + (1-\alpha)(\bar{x},\bar{y}) \in P$ (3)

[P5] Minimum extrapolation
P is the intersection set of all $\widehat{P}$ satisfying P1 to P4.

Based on these properties, we can write the technical envelope of the observed data as following (Piot and Vermersch (1992)) :

$$P = \{ (x,y) / x \geq \sum_{j=1}^{J} \lambda_j x_j, y \geq \sum_{j=1}^{J} \lambda_j y_j, \sum_{j=1}^{J} \lambda_j = 1, \lambda_j \geq 0 \; for \; all j = 1,\dots,J \} \quad (4)$$

However, some factors cannot be adjusted to their optimal level.

Most of farms can only adjust a sub-vector of inputs, labelled variable inputs.

Suppose that $(x_{Vj}, x_{Fj}) \in R_+^N$ is a decomposition of the input vector x_j into variable and quasi-fixed inputs, respectively, we have :

$$P = \{ (x_V, x_F, y) / x_V \geq \sum_{j=1}^{J} \lambda_j x_{Vj}, x_F \geq \sum_{j=1}^{J} \lambda_j x_{Fj}, y \leq \sum_{j=1}^{J} \lambda_j y_j, \sum_{j=1}^{J} \lambda_j = 1, \lambda_j \geq 0 \; for \; all \; j = 1,\dots,J \} (5)$$

P is the same data envelope as before but now this writing of the production set would allow the distinction between being efficient when some inputs are fixed or when all inputs are variable.

3. MEASURING TECHNICAL EFFICIENCY

We consider, here, the definition of a technically inefficient unit in the context of input reduction where the objective is to minimise the consumption of factors, given a particular output level. Thus, in this context, a given firm is considered to be technically inefficient if some other firms or some convex combinations of other units can : (i) produce at least the same amount of each output and (ii) use less of at least one input and no more of any other inputs.

The following programming measures technical efficiency, for each firm :

$$Min \; h_x^j$$

subject to

$$\begin{cases} h_x . x_j \geq \sum_{j=1}^{J} \lambda_j x_j \\ y_j \leq \sum_{j=1}^{J} \lambda_j y_j \\ \sum_{j=1}^{J} \lambda_j = 1 \\ \lambda_j \geq 0 \; for \; all j = 1,\dots,J \end{cases} \quad (6)$$

In this problem, the inability to be on the frontier of a technology set P is described by the inverse of the function distance of Shephard (1970) h_x^J. This formulation has been introduced by Banker, Charnes and Cooper (1984).

The vectors x_j and y_j are the inputs and outputs of the j^{th} firm. The scalar h_x^j can range from zero to one. One represents a farm that is technically efficient ; it is impossible to produce the outputs of farm j using a linear combination of inputs used by the other firms.

Alternative specifications for technical efficiency can be found in Färe, Grosskopf and Lovell (1985).

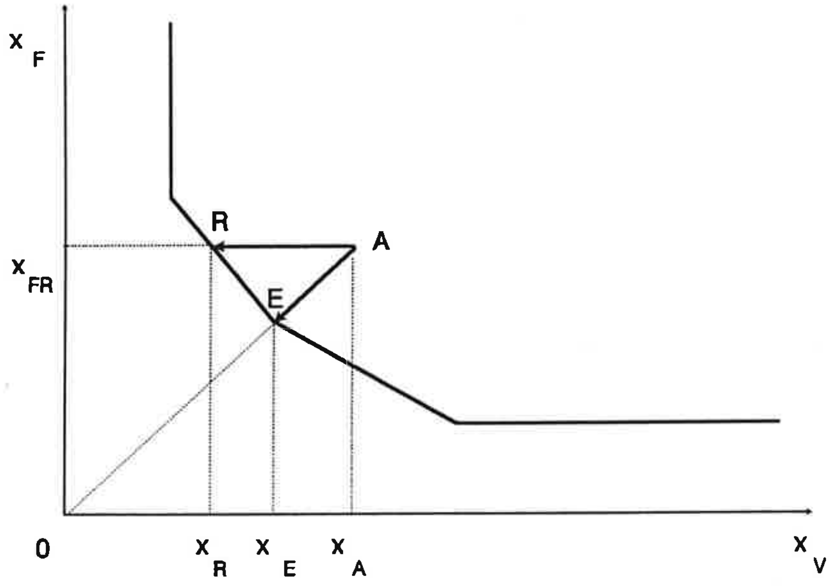
To measure technical efficiency conditional upon quasi-fixed inputs, we need to divide the input vector into two components : the quasi-fixed inputs x_{Fj} and the variable inputs x_{Vj} with $(x_{Vj}, x_{Fj}) \in R_+^N$. So, we have the following linear programming problem :

$$
\begin{aligned}
& Min\ h_{x_V}^j \\
& subject\ to \\
& \begin{cases}
h_{x_V}^j . x_{Vj} \geq \sum_{j=1}^{J} \lambda_j x_{Vj} \\
x_{Fj} \geq \sum_{j=1}^{J} \lambda_j x_{Fj} \\
y_j \leq \sum_{j=1}^{J} \lambda_j y_j \\
\sum_{j=1}^{J} \lambda_j = 1 \\
\lambda_j \geq o\ for\ all\ j = 1, \dots, J
\end{cases}
\end{aligned} \qquad (7)
$$

In this context of resource reduction with quasi-fixed inputs, a given firm is considered to be technically inefficient if some other firms or some convex combinations of other units can : (i) produce at least the same amounts of all outputs, (ii) use less of at least one variable input and no more of any other variable inputs and (iii) conserve the same level of quasi-fixed inputs.

Figure 1 gives an illustration, in the particular case of single output technology (Tauer, 1993). Given an piece wise linear isoquant, which manifests the convexity assumption and given an efficient firm in the interior at point A, the technical efficient point for that firm is E. x_V and x_F can be reduced, for a saving in x_V of $(x_{VA} - x_{VE})$. However, if x_F is fixed at x_{FR}, the amount that x_V must be reduced to reach the isoquant is the larger amount of $(x_{VA} - x_{VR})$, leading to a larger inefficient measure.

Figure 1. Maximum Reduction in Input x_V, Given Fixed Input x_F



4. DATA

Data were obtained from the FADN (Farm Accountancy Data Network) in 1990. Farms are specialised into cereal production : hard wheat, soft wheat, corn, summer barley and winter barley. Rice producers are not included in the sample. The data set contains 188 complete farm records. 91 % of them are individual producers and most of them are located in different areas. Nevertheless, near 30 percent are from the region Centre, 16 % from Ile-de-France and 12 % from Aquitaine.

The nonparametric approach allows us to describe multiple outputs. These farms primarily produced cereals, on average, for 71 % of total output. Other productions are aggregated into the other products variable. The total sale is, on average, 686 180 F for 82 ha of land, divided into 59 ha of land for cereal and 22 ha for other productions.

Land will constitute the quasi-fixed input of this analysis. The three variables input defined were labour (both family and hired labour), material expenditures of the year and raw materials. The last variable contained all the spending concerning production : fertilisers, fuel, feed for animals,...

The means and standard deviations of these variables are listed in Table 1.

Table 1. Summary of Data for Efficiency Analysis, (188 cereal producers, 1990)

	Units	Mean	Std-Dev.
Outputs			
Cereals	F (1)	487 171.7	303 618.2
Other products	F	199 014.0	141 786.4
Quasi-fixed inputs			
Cereal acreage	ha	59.5	32.4
Other acreage	ha	22.4	18.1
Variable inputs			
Labour	1/100 UTA (2)	136.3	50.9
Material expenditures	F	136 443.2	83 787.8
Raw materials	F	225 425.8	125 972.0

(1) F : French francs
(2) UTA : Labour units per year (1 UTA = 2200 hours of labour).

5. RESULTS

Technical inefficiency of a farm is determined relative to other similar units and depends on the number of observed data in the sample and on the selection of variables. The introduction of new characteristics about farms would modify the results.

First, when all inputs are variables, these 188 observed farms are, on average, 0.89 technically efficient. About 55 of them are technically efficient and 59 are nearly so (> 0.99). A radial reduction of the variable inputs will lead to a 11 % proportional contraction of them . But, when model (6) is solved by linear programming techniques, there is a transformation of it, which can be formulated as :

$$Min\left\{h_x^j - \varepsilon\left(\sum_{m=1}^{M} S_{mj}^- + \sum_{n=1}^{N} S_{nj}^+\right)\right\}$$

subject to

$$\begin{cases} h_x^j.x_j - S_j^+ = \sum_{j=1}^{J}\lambda_j x_j \\ y_j + S_j^- = \sum_{j=1}^{J}\lambda_j y_j \\ \sum_{j=1}^{J}\lambda_j = 1 \\ \lambda_j, S_j^+, S_j^- \geq 0 \text{ for all } j = 1,\dots,J \end{cases} \quad (8)$$

where $\varepsilon > 0$ is a small non Archimedean quantity and S^+ and S^- the slack variables.

Model (8) provides extra information pertaining to efficiency improvement. From the objective function, it is clear that the conditions for a farm to be Pareto efficient are $h_x^* = 1$ and $S^{+*} = S^{-*} = o$ where "*" indicates an optimal solution. If a farm is not efficient, the constraints in model (8) imply that by increasing y_{mj} by S_{mj}^{-*} and decreasing x_{nj} by $(1-h_x^{*j})x_{nj} + S_{nj}^{+*}$ the associated farm becomes efficient (Charnes and al., 1978). Of course, every efficient farm must have zero value for all slack variables.

Means and standard deviations of the optimal level of the variables are listed in table 2. There is, on average, a 17.9 % total resource reduction and a 1.6 % total product augmentation.

Table 2. Summary of Optimal Level of the Variables (land is variable)

	Units	Mean	Std-Dev.
Outputs			
Cereals	F (1)	489 692.9	302 733.6
Other products	F	205 075.2	138 112.4
Inputs			
Cereal acreage	ha	48.5	28.3
Other acreage	ha	16.8	16.4
Labour	1/100 UTA (2)	115.9	43.9
Material expenditures	F	116 623.2	75 257.1
Raw materials	F	188 033.6	112 231.6

(1) F : French francs
(2) UTA : Labour units per year.

The input reduction could be broken down into, on average, 21.7 % for land and 15.3 % for other factors.

Now, suppose that land allocation is a quasi-fixed input. These 188 observed farms are, on average, 0.88 technically efficient. About 54 of them are technically efficient and 59 are nearly so (> 0.99). The radial reduction of the variables will conduce to a 12 % proportional contraction . Nevertheless, with the existence of stock variables, we obtain on average a 16.8 % reduction for all inputs. It can be divided into 18.16 % for quasi-fixed factors and 16 % for the other ones. It's associated with a 1.6 % output increase.

Table 3. Summary of Optimal Level of the Variables (land is quasi-fixed)

	Units	Mean	Std-Dev.
Outputs			
Cereals	F (1)	489 986.2	302 533.0
Other products	F	204 310.1	138 463.0
Quasi-fixed inputs			
Cereal acreage	ha	50.1	28.0
Other acreage	ha	17.8	16.3
Variable inputs			
Labour	1/100 UTA (2)	114.5	44.1
Material expenditures	F	115 060.9	75 707.7
Raw materials	F	188 285.2	111 988.0

(1) F : French francs
(2) UTA : Labour units per year.

So, the average farm could obtain a total sale of 694 770 F for 65.3 ha of land when all inputs are variable. If land is a quasi-fixed input, then the average farm could obtain a total sale of 694 296 F for 67.9 ha of land. Notice that the variation of variable factors is more important. Therefore, if all farm reduce their technical inefficiency, an increase in production would be possible in response to a reduction of total inputs.

Now, suppose that all farms reduce their technical inefficiency. it could result an increase of cereal yields (Table 4).

Table 4. Cereal yield evolution

F/ha	Mean	Std-Dev
Initial yields	8 063	2 425
Optimal yields		
land is quasi-fixed	9 447 (+17 %)	2 566
land is variable	9 838 (+22 %)	2 652

When all inputs are variable, on average a 17.9 % contraction for all the inputs associated with a 1.8 % output expansion will allow a maximal 22 % increase in cereal yield. In the other case (land being quasi-fixed) a maximal 17 % increase in cereal yield is possible associated with a 16.8 % input decrease and a 1.6 % output increase.

Increasing farms efficiency implies private and social benefits. The efficiency measures are based on the hypothesis : that producers are not to be on the technology frontier. Moreover, these measures don't provide the path to reach the frontier of production but a set of points on this frontier that can be achieved. Consequently, an inefficiency measure could seem to be possible and only reflects the ignorance of economists. Other factors, like risk aversion, for example, could explain producer behaviour.

In the next section, we consider stronger hypothesis since producers are supposed to be on the technology frontier. The potential evolution of cereal yields, is then described in this context.

6. PARAMETRIC MODEL WITH TWO FACTORS

In the fourth part, we consider a monoproduct cereal technology described by the following production function :

$$y = Ax^{\alpha}T^{\gamma} \tag{9}$$

Quantity y is the cereal product, valued before the CAP reform with price p_o. Assuming $\alpha+\gamma<1$, we dispose of a "Cobb-Douglas" technology with decreasing returns to scale and two production factors. The aggregate quantity x (corresponding to price w_x) indicates the different materials (fertilisers, pesticides, seeds, ...) when T (corresponding to price w_T) represents land input which is supposed to be fixed in the short run. The constant parameter A denotes the other production inputs (capital, labour) and should combine an index of technical progress.

Formally, the cereal reform is described by :

- a new cereal price : p_1 (after a three years decrease)

- a distinction between small producers and professional ones corresponding to a threshold of 92 tonnes of cereals

- a rate of set-aside applied to the professional producers and equal to $1-\rho$ (=15 %)

- a regional average yield, r, on which is index-linked the compensatory payment.

The farmers are assumed to be price-efficient. Then, they maximise before the CAP reform the profit :

$$\underset{x,T}{Max}\left(p_0 A x^{\alpha} T^{\gamma} - w_x.x - w_T.T\right) \qquad (10)$$

The production possibility set related to (9) being convex, the first order conditions are sufficient ; in terms of optimal cereal yield, that leads to the following solution :

$$r_0^* = \frac{y_0^*}{T_0^*} = \frac{w_T}{p_0 \gamma} \qquad (11)$$

This last expression denotes a first effect attenuating the expected yield decrease in the close future of the CAP reform. Indeed, (11) shows that if p_0 decreases, there is an increase in the cereal yield.

This outcome is due to the decreasing returns to scale property of the technology which implies when p_0 decreases, a relatively more important decrease of T_0^* than y_0^*.

Program (10) occurs in the long run when land allocation can be freely adjusted. According to the different regions, the farmers could take advantage of possibilities of restructurations allowing an optimal adjustment of land allocation. In the case where this last factor is fixed, farmers maximise the restricted profit :

$$\underset{x}{Max}\left(p_0 A x^{\alpha} T^{\gamma} - w_x.x\right) \qquad (12)$$

One may deduce the optimal yield before CAP reform :

$$\bar{r}_0 = \left[\frac{w_x^{\alpha} T^{1-\alpha-\gamma}}{A(p_0\alpha)^{\alpha}}\right]^{\frac{1}{\alpha-1}} \qquad (13)$$

Situation in the post-reform differs also according to the following modalities : small producers (*pp*), professional producers (*PP*). In this last case, and assuming land freely variable, the behaviour program is now :

$$\underset{x,T}{Max}\ \left(p_1 A x^{\alpha}(\rho T)^{\gamma} - w_x.x - w_T T + (p_o - p_1) r T\right) \qquad (14)$$

The (PP) producers are constrained by a 15 % set-aside in order to profit by the compensatory payment $(p_o - p_1) r T$ which can be decomposed in :

. $(p_o - p_1) r \rho T$: for the cultivated hectares (45 ECU/tonne for a target price equal to 110 ECU/tonne)

. $(p_o - p_1) r (1-\rho) T$: compensatory payment for a 15 % set-aside.

In fact, the regional average yield can vary following the distinction between irrigated acreage, area in set-aside, cultivated acreage, ...

Program (14) differs also in the case of "small producers" and according to the land fixity ; table 5 recapitulates the different cases in terms of optimal cereal yield.

Table 5. Optimal Cereal Yield Evolution

Modality	$(PP),(\overline{T})$	$(PP),(T^*)$	$(pp),(\overline{T})$	$(pp),(T^*)$
Before the CAP reform	$\left[\frac{w_x^{\alpha} T^{1-\alpha-\gamma}}{A(p_o\alpha)^{\alpha}}\right]^{\frac{1}{\alpha-1}}$ (I)	$\frac{w_T}{p_o\gamma}$ (II)	$\left[\frac{w_x^{\alpha} T^{1-\alpha-\gamma}}{A(p_o\alpha)^{\alpha}}\right]^{\frac{1}{\alpha-1}}$ (III)	$\frac{w_T}{p_o\gamma}$ (IV)
Post reform	$\left[\frac{w_x^{\alpha} (\rho T)^{1-\alpha-\gamma}}{A(p_1\alpha)^{\alpha}}\right]^{\frac{1}{\alpha-1}}$ (Ia)	$\frac{w_T - (p_0 - p_1) r}{p_1 \gamma \rho}$ (IIa)	$\left[\frac{w_x^{\alpha} T^{1-\alpha-\gamma}}{A(p_1\alpha)^{\alpha}}\right]^{\frac{1}{\alpha-1}}$ (IIIa)	$\frac{w_T - (p_o - p_1) r}{p_1 \gamma}$ (IVa)

In the short run (characterised by land fixity), the optimal yield is a function of the variable input prices (w_x) and the other fixed factors (constant A) ; their foreseeable evolution (decrease of relative prices (w_x) provided by a lower demand, pursuit of technological innovations) would operate a new yield increase. In the long run where land is at optimum level, the cereal yield depends solely on the cereal-land price ratio and the related production elasticity γ.

Our purpose now is to compare for each group (I, II, III, IV) the situations before and after the CAP reform. The first group (I : professional producers, fixed land) shows two contrary effects as for the evolution of the cereal yields : a negative impact deriving from the cereal price decrease ; a positive effect following on from the obligation of set-aside at rate (1 - ρ). Taking into account the known values of ρ, p_1 et p_o, the consequence of these two effects leads without ambiguity to a cereal yield decrease.

We notice three effects for the second group (II : professional producers, land at optimum level) ; two positive impacts : the price-effect in a situation of decreasing returns to scale, a "negative direct payment effect". What will be the result ? The cereal farmers will be motivated to increase the cereal yield if :

$$\frac{w_T}{p_0 \gamma} < \frac{w_T - (p_0 - p_1)r}{p_1 \gamma \rho} \qquad (15)$$

so that :

$$w_T > \frac{(1-\lambda)p_o r}{(1-\lambda\rho)} \qquad (16)$$

with $\lambda = \frac{P_1}{P_o}$. Nevertheless, the present level of λ doesn't allow the precedent inequality to be verified. In fact, the right term of [15] can be compared to a "threshold price" for land. We calculated this threshold for each region (French "department") according to the regional average yield. The computed price ranges from 418 Ecu/hectare to 824 Ecu/hectare. Actually, these high values implicitly incorporate the allowance $(p_o - p_1)r$, foreshadowing so a risk in the medium run, namely a catching of the subsidy in land transactions (just as dairy farmers did when quotas were introduced in 1984). Each EEC member must be vigilant with respect to this latter effect ; indeed, the additional costs relative to land or to production rights will contribute to delay the acquiring of new gains in productivity stemmed from the adoption of technological innovations.

There is no ambiguity about the third group (III : small producers, land as fixed factor) insofar as there appears only one negative price-effect on cereal yield evolution. Lastly, we meet again in the fourth group (IV : small producers, land as variable factor) the effects which have been observed in the second group, except the set-aside one. For these two groups, the CAP reform finds expression in a variation of the cereal-land price ratio, from w_T/p_0 to $\frac{w_T - (p_o - p_1)r}{p_1}$: the direct payment leads to a decrease of land net cost.

We make clear also in table one the relative variation of the cereal yields provided by the CAP reform. Notation is slightly modified :

$w_{OT} = w_T$: land price before the reform

$w_{1T} = w_{OT} - (p_o - p_1)r$: net land price in the post reform.

Table 6. Relative Cereal Yield Variation

	$(PP),(\overline{T})$	$(PP),(T^*)$	$(pp),(\overline{T})$	$(pp),(T^*)$
$\frac{\Delta R}{R}$	$\frac{\alpha}{1-\alpha}\frac{\Delta p}{p}+\frac{\alpha+\gamma-1}{1-\alpha}(\rho-1)$ (I)	$-\left[1-\frac{w_{1T}p_o}{w_{oT}p_1\rho}\right]$ (II)	$\frac{\alpha}{1-\alpha}\frac{\Delta p}{p}$ (III)	$-\left[1-\frac{w_{1T}p_0}{w_{0T}p_1}\right]$ (IV)

The groups I and III (where land is hold fixed) rather describe the evolution in the short run. Group II and IV show that the yield decrease will be cancelled since net land price evolution follows the cereal price evolution, so that :

$$\frac{w_{1T}}{w_{oT}} = (\rho)\frac{p_1}{p_o} \qquad (17)$$

In connection with that, it seems important to model the prospective expectations relative to land transactions and taking into account the implicit rent provided by the subsidy quota. Recent work (Cavailhès et Richard, 1992) observes, at least in a few French regions, the necessary conditions for a rising land market. However, the long run dynamics of adjustment will be also strongly conditioned by the level of r, the regional average yield. Using the notion of shadow price, the next section states more precisely the future of cereal yields in terms of land adjustments.

7. SHADOW PRICE FOR LAND AND CORRELATIVE EVOLUTION OF CEREAL YIELDS

First of all we will recall the shadow price expression in the case of (PP) professional producers, constrained in the post-reform to land fixity. (PP) maximise the restricted profit, such as:

$$\pi_R(w_x, p_1, \rho, T) = \underset{x}{Max}\left(p_1 A x^{\alpha}(\rho T)^{\alpha} - w_x x\right) \qquad (18)$$

Noting $\overline{x_1}$, the solution of [17], the restricted profit function can still be written :

$$\pi_R(w_x, p_1, \rho, T) = w_x . \overline{x_1}\left(\frac{1}{\alpha} - 1\right) \tag{19}$$

Assuming that this function is twice differentiable with respect to its different arguments, we can define :

$$\overline{w_{1T}} = \frac{\partial \pi_R}{\partial T} = w_x \frac{\gamma}{\alpha} \frac{\overline{x_1}}{T} \tag{20}$$

$\overline{w_{1T}}$ is the shadow price for land and represents the marginal increasing of the restricted profit consecutive to a marginal increasing of T. The previous computation is reiterated according to the different cases (before the CAP reform, (pp)). Then, it is possible to express the optimal yields as functions of the shadow price $\overline{w_T}$: the outcome is presented in table 7.

Table 7. Shadow price, net price and cereal yield evolution

Modality	$(PP),(\overline{T})$	$(PP),(T^*)$	$(pp),(\overline{T})$	$(pp),(T^*)$
Before the CAP reform	$\frac{\overline{w_T}}{p_o\gamma}$ (I)	$\frac{w_T}{p_o\gamma}$ (II)	$\frac{\overline{w_T}}{p_o\gamma}$ (III)	$\frac{w_T}{p_o\gamma}$ (IV)
Post CAP reform	$\frac{\overline{w_T}}{p_1\gamma\rho}$ (Ia)	$\frac{w_T-(p_o-p_1)r}{p_1\gamma\rho}$ (IIa)	$\frac{\overline{w_T}}{p_1\gamma\rho}$ (IIIa)	$\frac{w_T-(p_o-p_1)r}{p_1\gamma}$ (IVa)

The analysis of table 7 shows that the shadow price identifies with the net land price in the case where land input is at a long run equilibrium. Indeed, taking again the (pp) example, the total profit function π_T, solution of (14) can still be written.

$$\pi_T(w_x, w_T, p_o, p_1, \rho, r) = \underset{T}{Max}\left(\pi_R(w_x, p_1, \rho, T) - [w_T - (p_o - p_1)r]T\right) \tag{21}$$

with the following first-order conditions :

$$\frac{\partial \pi_R}{\partial T} = w_T - (p_o - p_1)r \tag{22}$$

i.e. the equality between the shadow price and the net land cost in the post CAP reform. So, beyond the incitement provided by the CAP reform to reduce the technical inefficiencies, the direct payment per hectare will probably modify the dynamics of price-inefficiencies reduction.

Consequently, we must know if $T < T^*$ or $T > T^*$, T^* being the long run solution of (14) for T. In the short run of the post CAP reform, it seems likely that $T < T^*$ insofar as the direct payment implies a negative effect on the net land price. An econometric application on the restricted profit function should allow to compare (20) et (22) ; since $\overline{w_{1T}} \geq w_T - (p_o - p_1)r$, $\pi_R(w_x, p_1, \rho, T)$ concave in T [1], one may deduce that $T \leq T^*$. In a similar way, observing table 7, a shadow price greater than the net land price indicates a long run cereal yield lower than the optimal yield constrained by T: hence the land fixity in the short run reduces the expected yield decrease.

On the contrary, the Le Châtelier-Samuelson principle [2] expresses a reverse evolution if we consider a land fixity at a long run equilibrium. At this optimum, Le Châtelier principle says that the more markets we allow to adjust to the effects of a price increase in the first factor, the larger in absolute value the own-price elasticity for this first factors. The mechanism can be illustrated in our model ; let us consider the (pp) case. In the case where land is variable, the optimal yield before the reform is :

$$r = \frac{w_T}{p_0 \gamma} \tag{23a}$$

Identifying this expression with the land constrained optimal yield, we thus derive the optimal level T^*, i.e. :

$$T^* = \left[\frac{w_T^{\alpha-1} p_o A \alpha^{\alpha}}{w_x^{\alpha} \gamma^{\alpha-1}} \right]^{1/1-\alpha-\gamma} \tag{23b}$$

Let us assume now that in the post CAP reform, farmers may not adjust the preceding allocation for land. In that case, the optimal cereal yield is formalised as the expression (Ia) in table one with $T = T^*$(expression 22b). That gives :

$$\overline{r_1^*} = \frac{w_T}{p_1 \gamma \rho} \rho^{-\gamma/\alpha-1} \left(\frac{p_0}{p_1} \right)^{1/\alpha-1} \tag{23c}$$

as $p_1 < p_0$ and $\alpha + \gamma < 1$, $\overline{r_1^*}$ is lower that the optimal yield obtained with T freely variable, i.e. equal to $w_T / p_1 \gamma \rho$, without the direct payment effect.

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[1] $\pi_R(w_x, p_1, \rho, T)$ is concave in T because the production possibility set related to [8] is convex.

[2] See, for example, Lau (1976) , Diewert (1981).

The same argument can be applied to other factors such as family labour, hired labour or capital which cannot be instantaneously adjusted to the cereal price decrease. Moreover, the yield evolution will be strongly governed by the land transactions among cereal farms ; indeed, the CAP reform will explicitly entail trades from "low ability" to "high ability" farmers [3]. In other words, micro inefficiency reduction will probably occur at the same time as an adjustment of the overall agricultural economy towards a global production optimum, requiring an ever lower number of farms.

8. MODEL GENERALISATION - COMPARISONS BETWEEN REGIONAL AVERAGE YIELD AND OPTIMAL YIELD

Whatever the choice of the functional form and the number of inputs-outputs fixed or freely variable, the optimal yield expression presented in table 7 remains unchanged if we characterise γ as the estimated production elasticity at the observation level (γ_o or γ_1).

Let us first assume an optimal adjustment for every input and output. The farmer behaviour is expressed by :

$$\underset{x,y}{Max} \quad p_y{}'.y - w_x{}'.x$$
$$f(x,y) = o \qquad (\alpha) \tag{24}$$

w_x and p_y denote respectively the input and output price-vectors ; f represents the transformation function. Relatively to cereal-price p_c and land price w_T, first-order conditions are :

$$\frac{w_T}{P_c} = -\frac{f_T}{f_c} \tag{25}$$

with $f_T = \frac{\partial f}{\partial x_T}$ and $fc = \frac{\partial f}{\partial y_c}$. The optimal cereal yield can be written as :

$$r^* = \frac{y_C^*}{x_T^*} = \frac{y_C^* \cdot \frac{\partial y_C}{\partial x_T}}{x_T^* \cdot \frac{\partial y_C}{\partial x_T}} = \frac{\frac{\partial y_C}{\partial x_T}}{\gamma} \tag{26}$$

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[3] See, for example, Leathers, 1992.

with $\gamma = \dfrac{\partial \ln y_c}{\partial \ln x_T}$, the cereal production elasticity relative to land input. Moreover, by differentiating the technological constraint (α) we obtain :

$$\frac{\partial y_c}{\partial x_T} = -f_T \Big/ f_c \qquad (27)$$

and, by using (24) :

$$r = \frac{w_T}{p_c \gamma} \qquad (28)$$

i.e. the general expression of table 6 in the case of variable land.

Let's consider the more general case of a fixity for a sub-vector z. Expression (24) becomes :

$$\begin{aligned} &\underset{x,y}{Max}\left(p_y^{'}.y - w_x^{'}.x\right) \\ &y_c = f(x, y_{-C}, z) \end{aligned} \qquad (29)$$

Without loss of generality, the transformation function is expressed under an explicit form. First-order conditions lead to:

$$p\frac{w_i}{f_i} = -\frac{p_j}{f_i} (30)$$

i is the index for the variable factors, $j \neq c$ for the variable outputs. Moreover, the restricted profit function is :

$$\begin{aligned} \pi_R(p_y, w_x, z) &= \underset{x,y}{Max}\left(p_y^{'}.y - w_x^{'}.x; y_C = f(x, y_{-C}, z)\right) \\ &= p_y^{'}.\overline{y}(p_y, w_x, z) - w_x^{'}.\overline{x}(p_y, w_x, z) \end{aligned} \qquad (31)$$

$\overline{x}, \overline{y}$ being the solution of (29). One may deduce the expression of the shadow price for land by differentiating (31) with respect to z_T :

$$\frac{\partial \pi_R}{\partial z_T} = p_C . \frac{\partial \overline{y_C}}{\partial z_T} + \sum_{j \neq C} p_j . \frac{\partial \overline{y_j}}{\partial z_T} - \sum_i w_i . \frac{\partial \overline{x_i}}{\partial z_T} \qquad (32)$$

Using (30) and the fact that $\overline{y}_C = f(\overline{x}, \overline{y}_{-C}, z)$:

$$\overline{w}_T = \frac{\partial \pi_R}{\partial z_T} = p_C \cdot \left(\frac{\partial f}{\partial z_T} \right)_{\overline{x}, \overline{y}_{-C}, z_{-T}} \tag{33}$$

Then, the optimal cereal yield, in presence of fixed netputs becomes :

$$\overline{r} = \frac{\overline{y}_C}{x_T} = \frac{\frac{\partial y_C}{\partial z_T}}{\gamma} = \frac{1}{\gamma}\left(\frac{\partial f}{\partial z_T} \right)_{x, y_{-C}, z_{-T}}$$

or, by using (33) :

$$\overline{r} = \frac{\overline{w}_T}{p_C \gamma} \tag{34}$$

Therefore, we find again the general expression of table 7 ; in particular, the shadow price $\overline{w}_T$ and the production elasticity γ are functions of z which characterises the desequilibrium levels relative to certain netputs. We noted earlier that the future of cereal yields will be explained from the reduction of the allocative inefficiency related to the land input, otherwise from the convergence of $\overline{w}_T$ towards w_T. This reduction will be obtained as much by the land adjustment as by the adjustment of the other quasi-fixed netputs, according to their flexibility.

The functional form f can include also a technical progress parameter which affects temporally the technology ; it concerns for example family labour concerns saving,... So technological innovations leads to gains in productivity, these gains are lending themselves with difficulty to an econometric estimation : indeed, we meet identifiability problems with, for example, scale effects.

The preceding outcomes allow us to present a general measure of the yield relative variation including the different modalities ; such as :

$$\frac{\Delta R}{R} = \left(\frac{p_0 \gamma_0 \overline{w_{1T}}}{(\rho) p_1 \gamma_1 w_{0T}} \right) \tag{35}$$

$\overline{w}_{oT}$ and $\overline{w}_{1T}$ represent respectively the land shadow prices before and after the CAP reform. These prices are, in a way, a dual measure of the netput desequilibrium insofar as they are derived from the restricted profit function ; they are equal to the net land price in the case where this last input is optimally adjusted. The terms γ_0 *and* γ_1 refer to the land production elasticities respectively estimated before and after the CAP reform. The corrective term ρ is added in (35) for the modality "professional producers".

Whatever the situation, small producer or professional one, land as fixed input or freely variable, the cereal price effect implies clearly a yield decrease. However, an econometric application should allow to measure the range of the other yield increasing effects : set-aside, decreasing returns to scale, quasi-fixity,... In other respects, this application demands a dual approach to estimate the land shadow prices (expression (35)), hence the construction of prices (cost for capital services, implicit prices,...). Such an approximation is risky on individual farm data and catches the technical and allocative inefficiencies which characterise number of farms. An other reason leads to be very careful in using the econometric approach. Indeed, we argued our model in a partial equilibrium framework, taking into account some netputs which can freely be adjusted in the medium or long run. Therefore, is the subset of variable inputs relevant in the case of a cereal price decrease ? Otherwise, the idea lies to take into account a partial equilibrium analysis including prices and quantities the more flexible to the cereal price decrease. For example, observing the recent price fluctuations of raw materials, it seems likely that the cereal price effect will be also attenuated in the short run by an price-adjustment of the other agricultural inputs : fertilisers, pesticides,... So, we recall the generalised Le Châtelier principle according to the more markets that adjust to the price decrease in the first market, the smaller the elasticity of derived supply becomes in the first market (Diewert, 1981).

9. CONCLUSION

The cereal yield evolution has been analysed considering the different situations of microeconomic efficiency, since technical inefficiency until price efficiency. This level will probably influence the efficiency of the cereal market regulation. In other respects, the model displays the different effects of the direct payments on the agricultural supply structure.

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